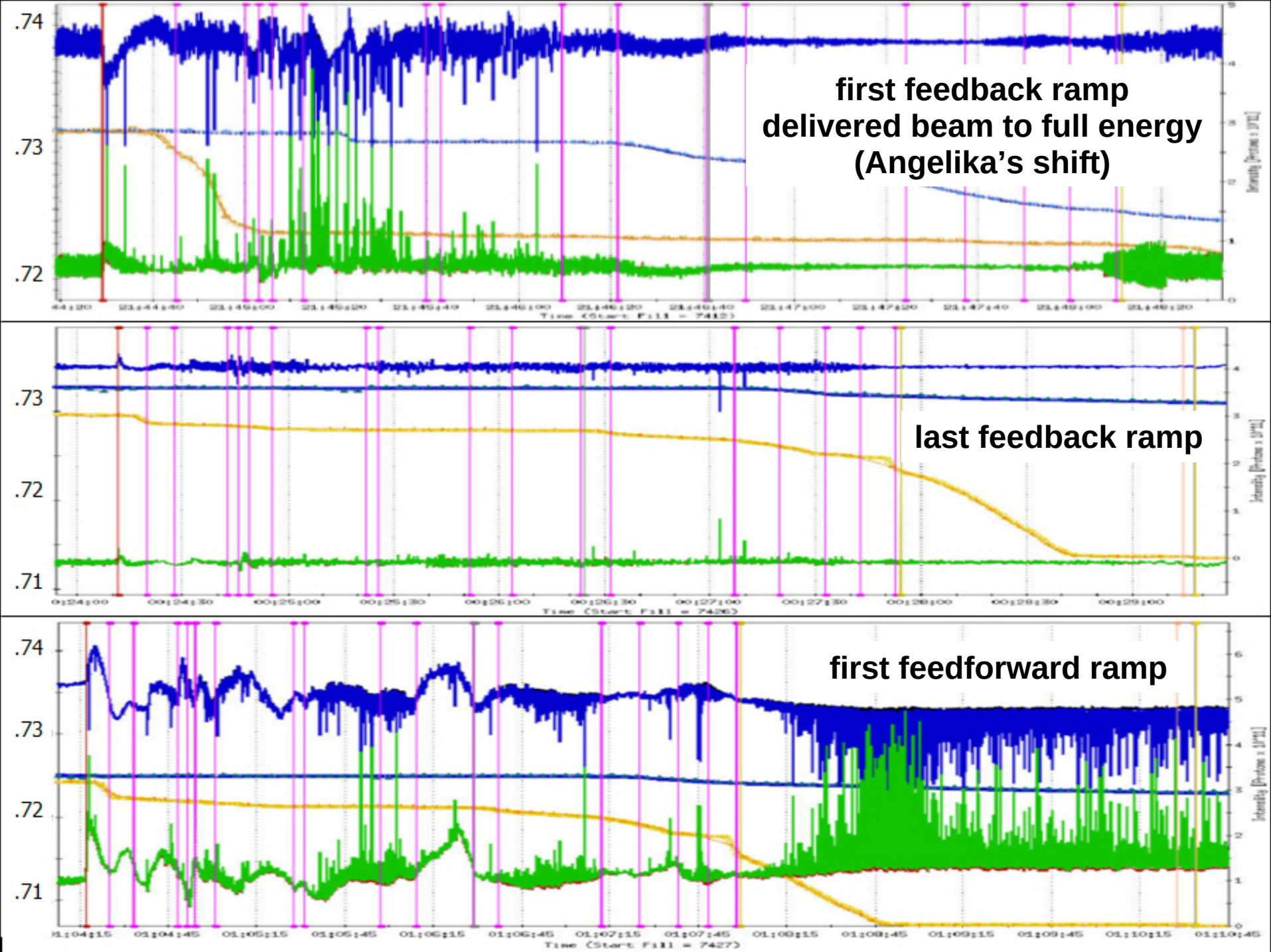
Operational
Chromaticity, Coupling, and Tune Feedback
for RHIC Run 7

Outline

- (Very Brief) results from Run 6 100 GeV (one slide)
- Issues for ‘Tune Feedback’
- 90 degree phase jumps
- Mains Harmonics
- Chromaticity
  - what we think we’ve learned
  - proposal for Run 7
- Conclusions, plan for Run 7

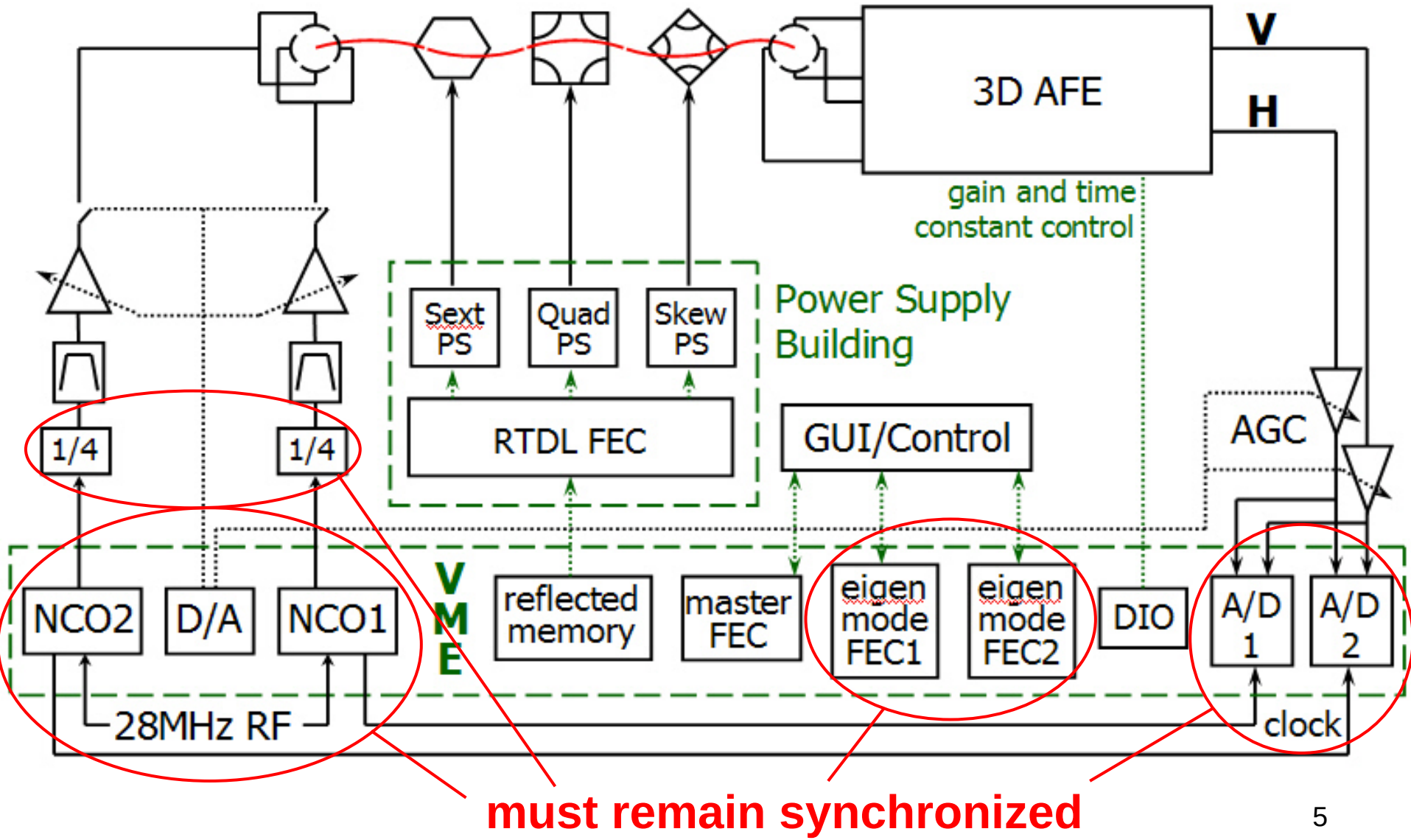

.74
.73
.72
first feedback ramp
delivered beam to full energy
(Angelika's shift)
.73
.72
.71
last feedback ramp
.74
.73
.72
.71
first feedforward ramp

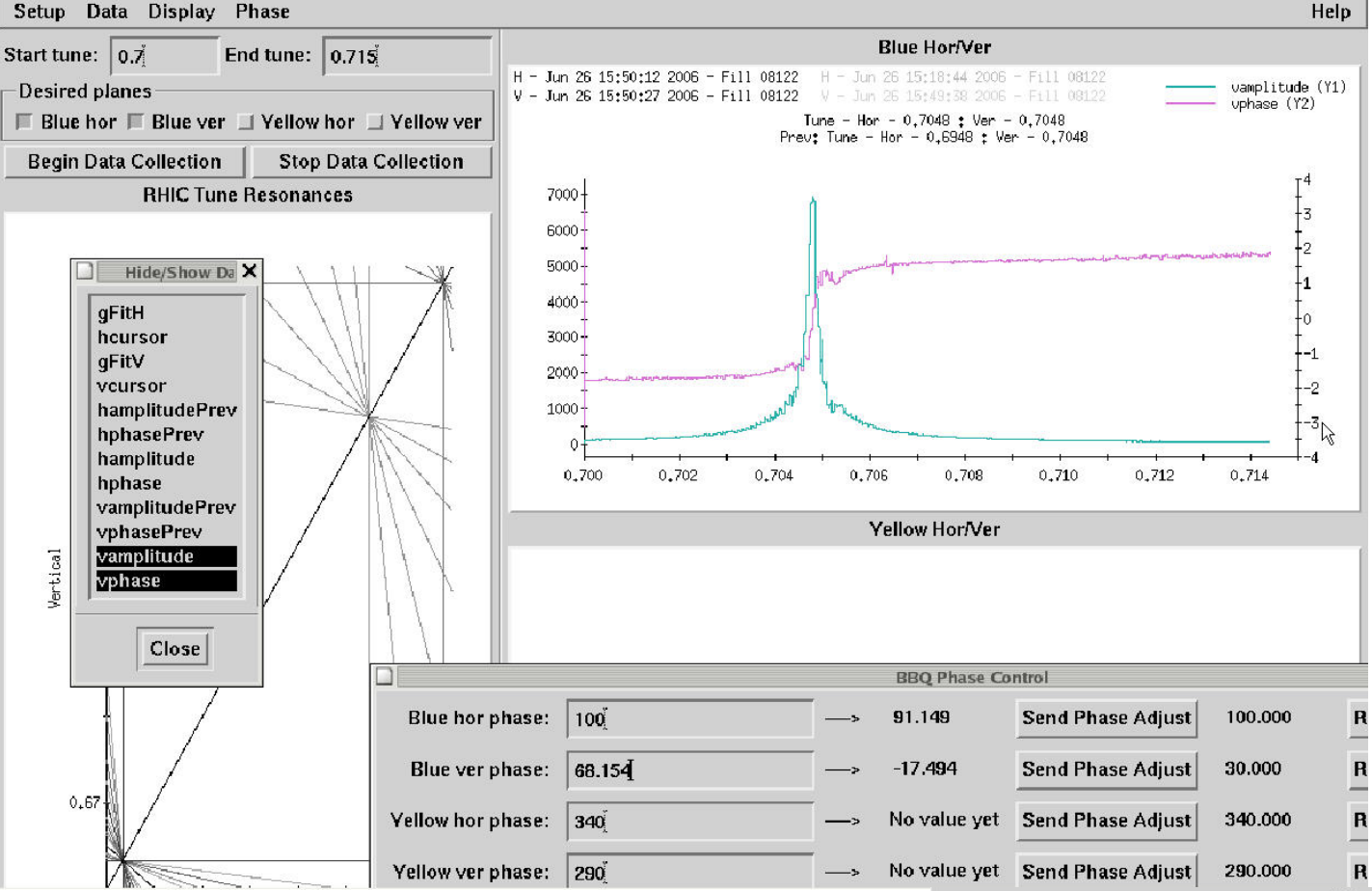
Issues for Tune Feedback

- Dynamic Range **done**
  - ~180dB (or more) required
  - solution - Direct Diode Detection (3D) AFE
- Coupling **done**
  - drives tune feedback loop unstable
  - solution – continuous coupling measurement and feedback
- 90 degree phase jumps **in the works**
  - digitizer clock loses synchronization
  - solution – fit phase to chirped BTF
- Mains Harmonics **in the works?**
  - direct excitation of betatron resonance by high harmonics of power supply frequencies
  - mechanism is not yet understood
  - amplitude is ~70dB above 3D AFE noise floor during ramping
  - solution??? just live with it?
- Chromaticity **in the works**
  - modifies Beam Transfer Function portion of overall loop gain
  - affects system stability, tracking ability,…
  - solution – continuous chromaticity measurement and feedback

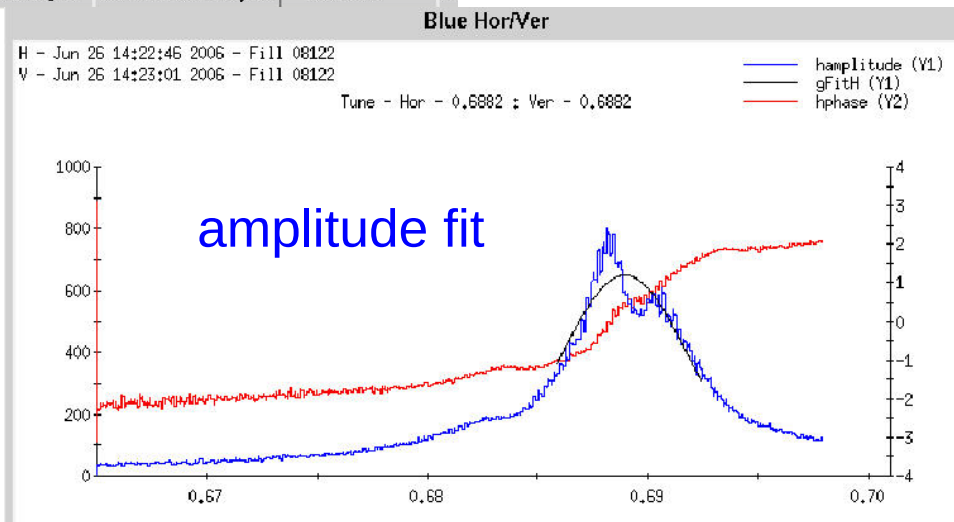
one ring

System Block Diagram for RHIC Run 6





Jon Laster's BTF Application expanded to include amplitude fit and phase correction (essential for non-specialist operation)

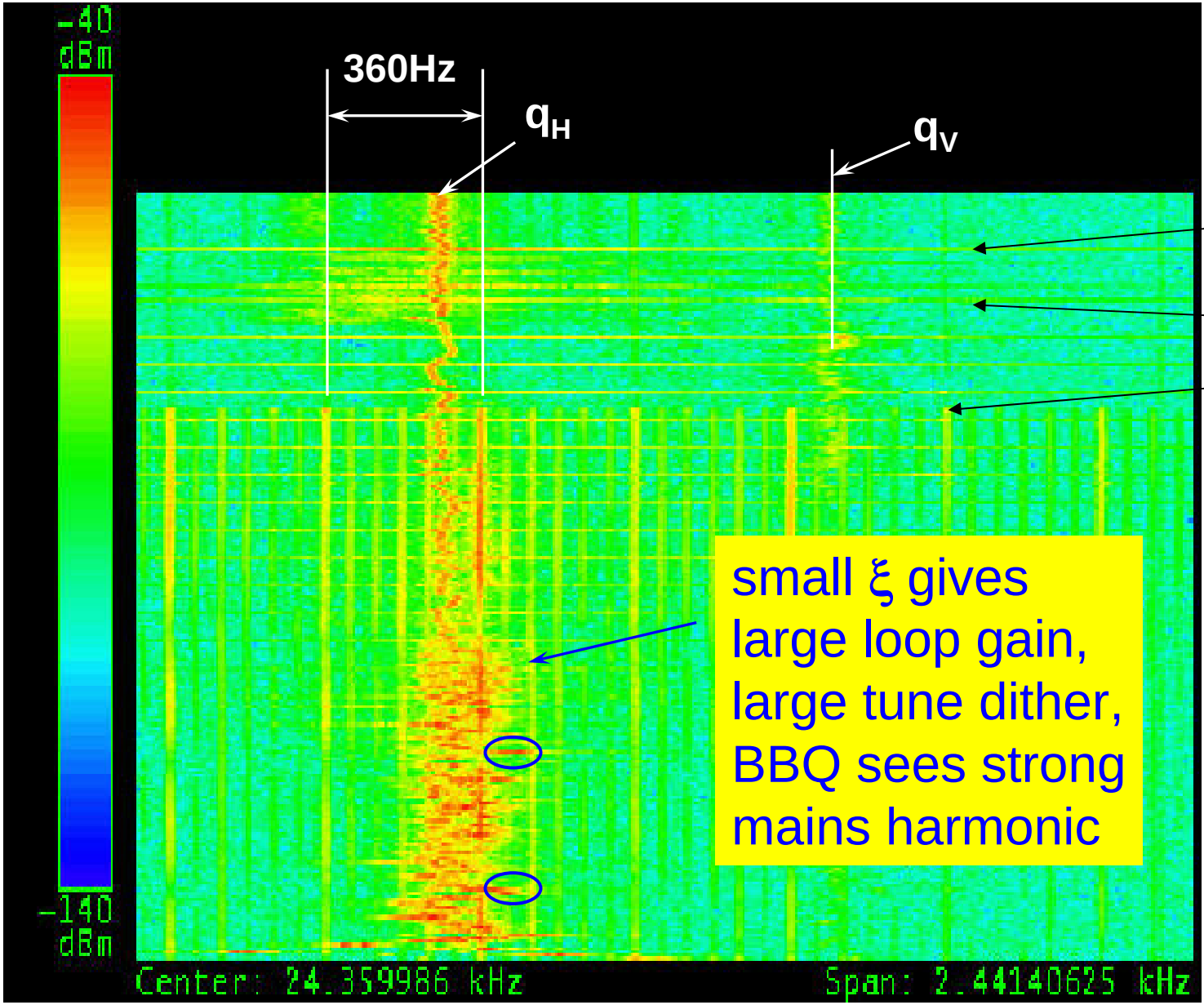


For Run 7:

- Move to ADO to permit faster BTF (chirp)
- Improve fit algorithm
- Tie to sequencer

Mains Harmonics

- direct excitation of betatron resonance by high harmonics of power supply frequencies
- mechanism is not yet understood
- large amplitude
  - ~40dB above 3D AFE noise floor during injection and store (~1μ)
  - ~70dB above 3D AFE noise floor during ramping (~30μ)
- three definitive measurements
  - increase/decrease coincides with ramping supplies
  - coupling moves harmonics into vertical
  - main dipole 12 phase power supply tweak modifies spectrum
- No obvious improvement with additional filtering added for 250GeV ramps (but don't remove it!)
- Plan???? live with it



RF loops close, IPM and Artus kicking (!!!)

accramp (?)

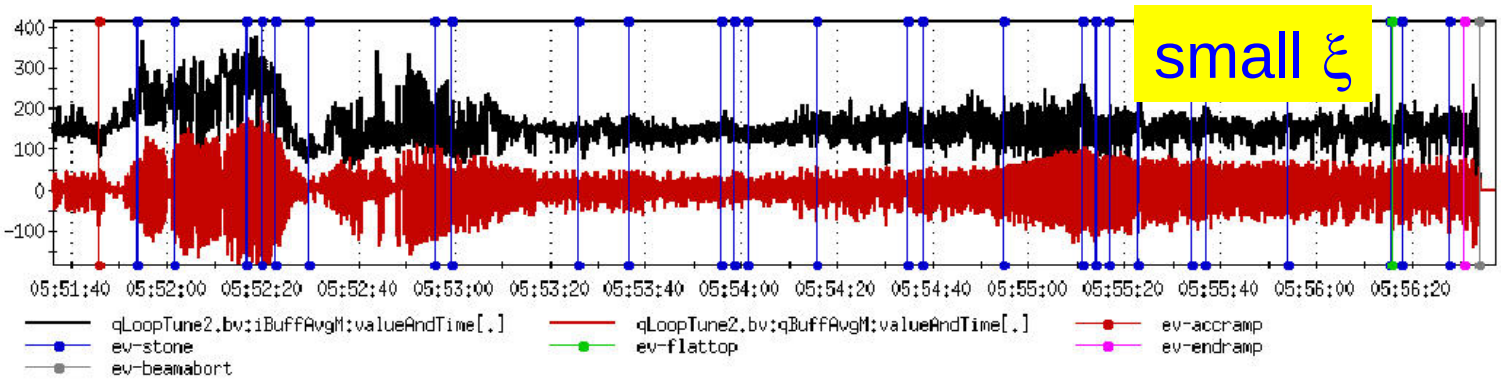
main dipole ramping supply turns on

Chromaticity – what we learned from 250GeV

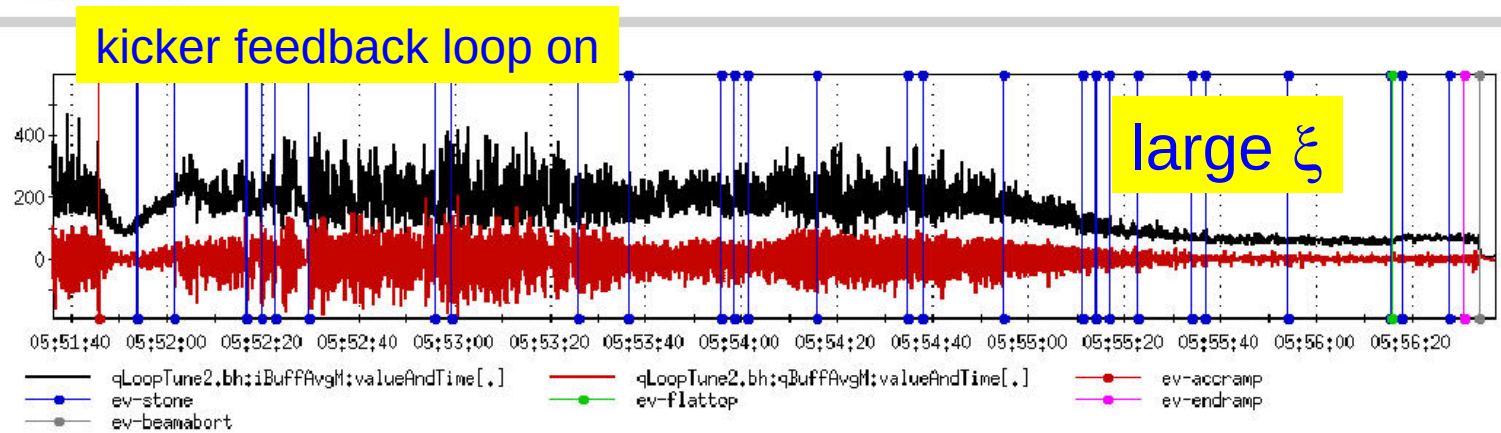
- Weak sensitivity to chrom with 245MHz PLL
  - linewidth is dominated by $N\eta dp/p$
- Much stronger sensitivity with BBQ – two effects
  - amplitude response is increased/diminished
  - phase slope changes
  - **both affect overall loop gain – what we have to stabilize**
- Chromaticity too large
  - loop gain becomes too small, can't track fast tune changes
- Chromaticity too small
  - 3D AFE is peak detector, sensitive to 'micro-instabilities'
  - BBQ becomes unstable, repeatedly loses and regains lock
- Acceptable range for BBQ is only a very few units

Blue Ring 250GeV ramp

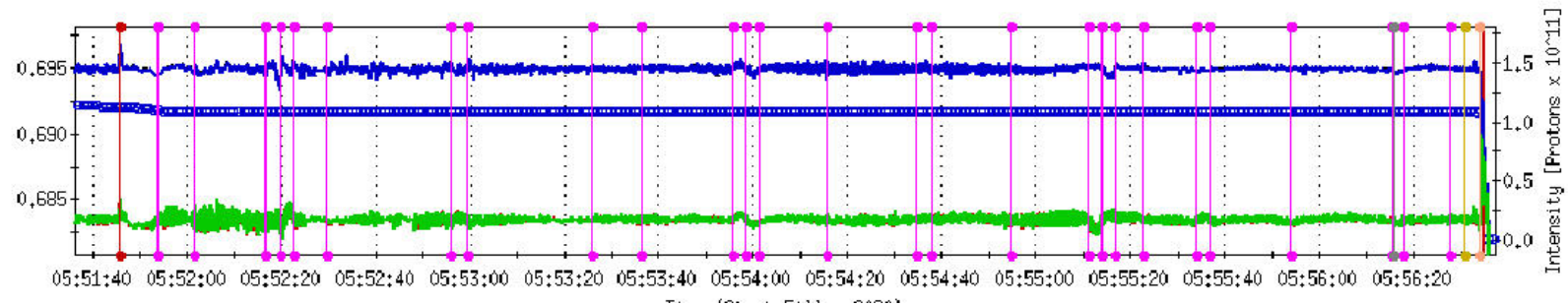
vert
I and Q



horiz
I and Q

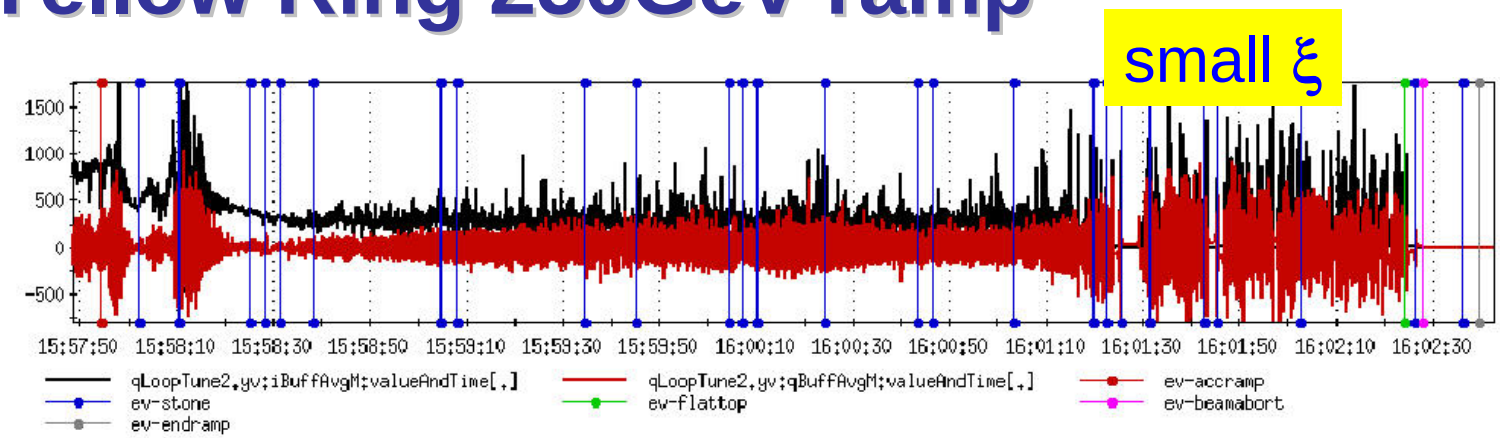


tunes
and
beam
current

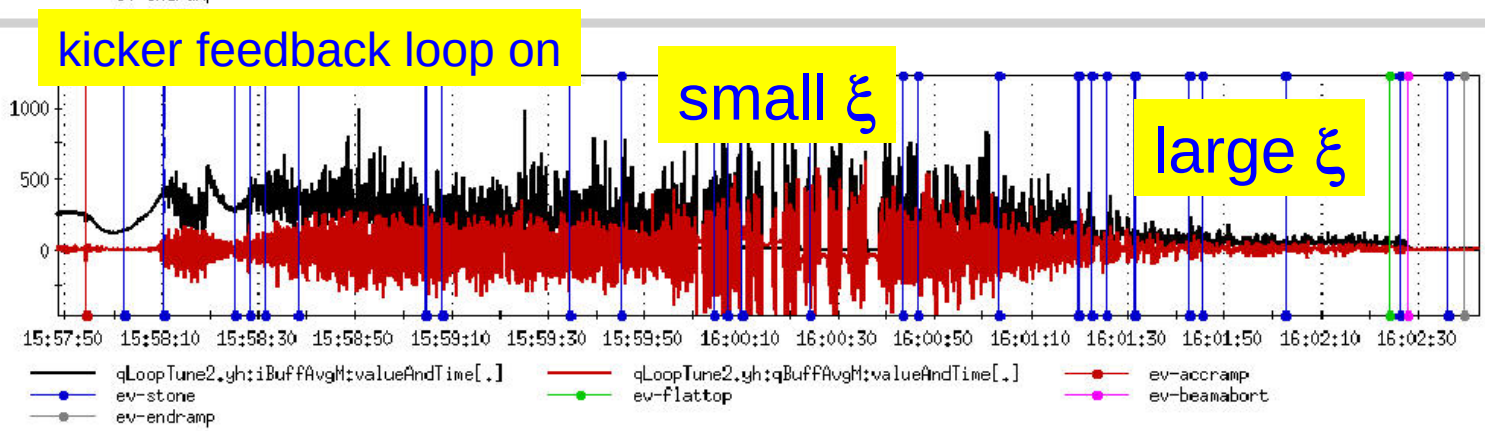


Yellow Ring 250GeV ramp

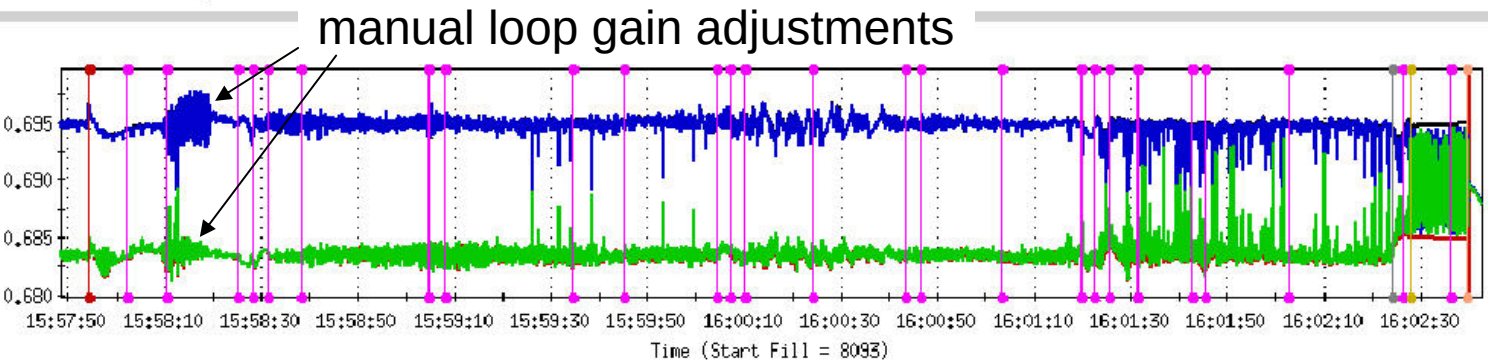
vert
I and Q

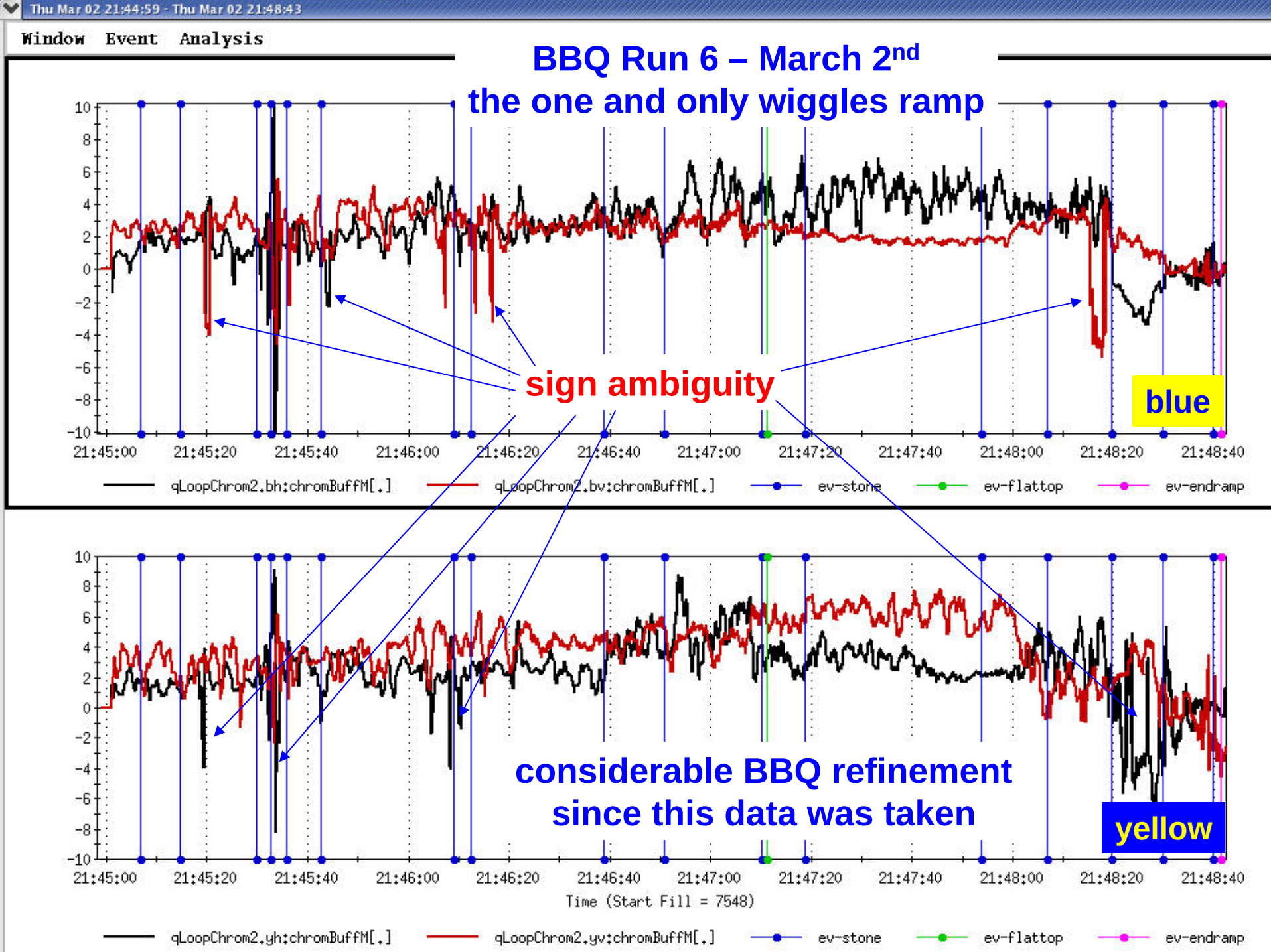


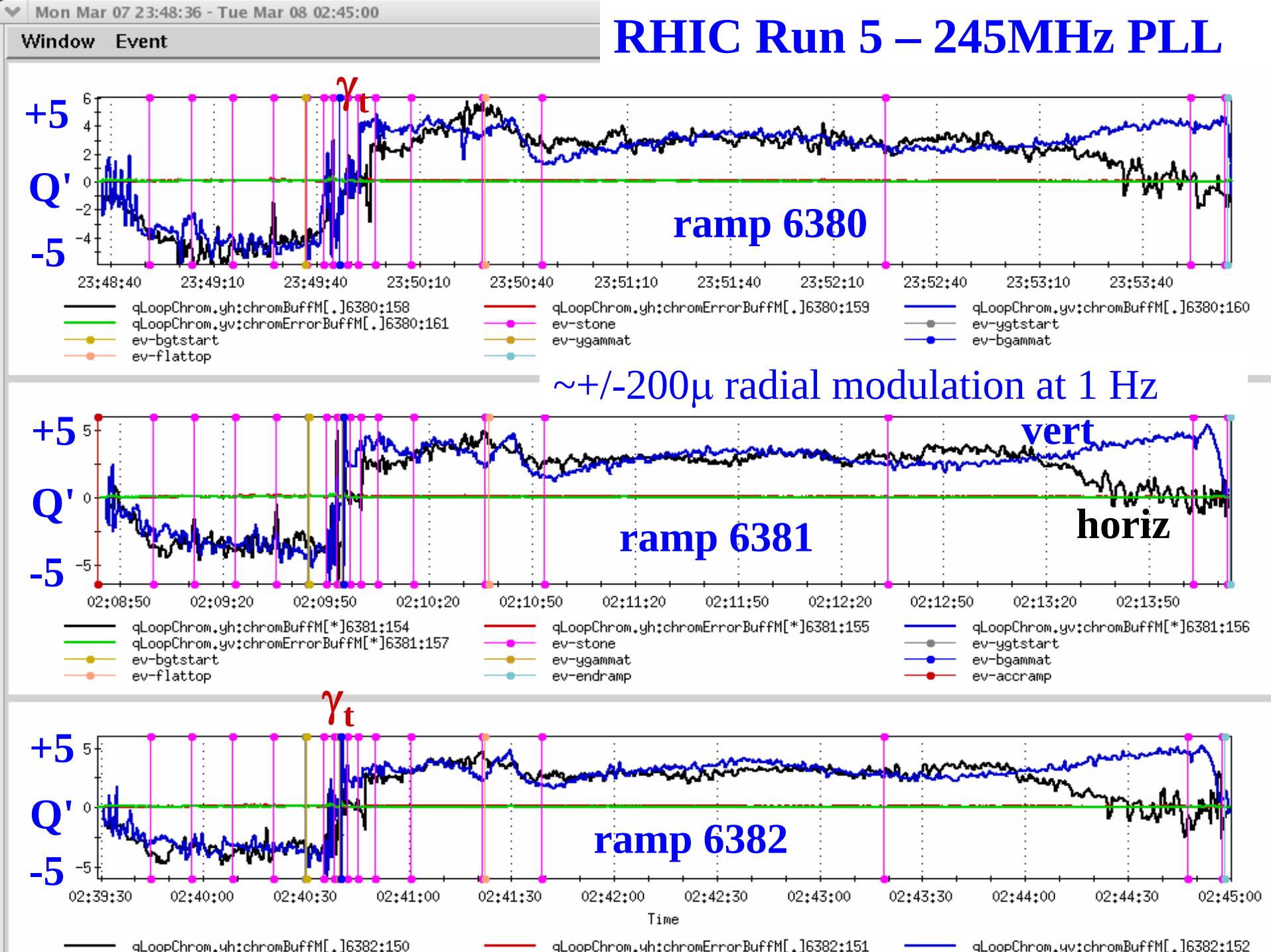
horiz
I and Q



tunes




Thu Mar 02 21:44:59 - Thu Mar 02 21:48:43
Window Event Analysis
BBQ Run 6 – March 2nd
the one and only wiggles ramp
sign ambiguity
blue
considerable BBQ refinement
since this data was taken
yellow
Time (Start Fill = 7548)
qLoopChrom2.bh:chromBuffM[.]
qLoopChrom2.bv:chromBuffM[.]
qLoopChrom2.yh:chromBuffM[.]
qLoopChrom2.yv:chromBuffM[.]
ev-stone
ev-flattop
ev-endramp

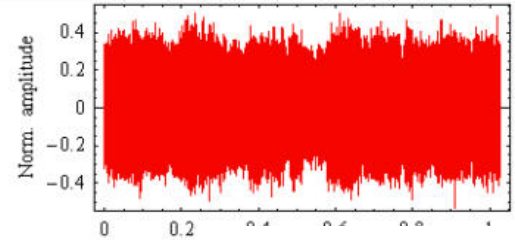

Mon Mar 07 23:48:36 - Tue Mar 08 02:45:00
Window Event
RHIC Run 5 – 245MHz PLL
γt
+5
Q'
-5
ramp 6380
23:48:40 23:49:10 23:49:40 23:50:10 23:50:40 23:51:10 23:51:40 23:52:10 23:52:40 23:53:10 23:53:40
qLoopChrom.yh:chromBuffM[.]6380:158
qLoopChrom.yv:chromErrorBuffM[.]6380:161
ev-bgtstart
ev-flattop
qLoopChrom.yh:chromErrorBuffM[.]6380:159
ev-stone
ev-ygammat
qLoopChrom.yv:chromBuffM[.]6380:160
ev-ygtstart
ev-bgammat
~+/-200μ radial modulation at 1 Hz
vert
horiz
ramp 6381
02:08:50 02:09:20 02:09:50 02:10:20 02:10:50 02:11:20 02:11:50 02:12:20 02:12:50 02:13:20 02:13:50
qLoopChrom.yh:chromBuffM[*]6381:154
qLoopChrom.yv:chromErrorBuffM[*]6381:157
ev-bgtstart
ev-flattop
qLoopChrom.yh:chromErrorBuffM[*]6381:155
ev-stone
ev-ygammat
ev-endramp
qLoopChrom.yv:chromBuffM[*]6381:156
ev-ygtstart
ev-bgammat
ev-accramp
γt
+5
Q'
-5
ramp 6382
02:39:30 02:40:00 02:40:30 02:41:00 02:41:30 02:42:00 02:42:30 02:43:00 02:43:30 02:44:00 02:44:30 02:45:00
Time
qLoopChrom.yh:chromBuffM[.]6382:150
qLoopChrom.yh:chromErrorBuffM[.]6382:151
qLoopChrom.yv:chromBuffM[.]6382:152

More on Chromaticity Measurement

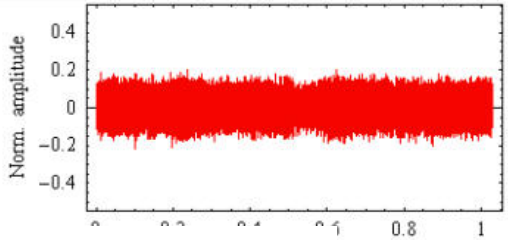
- General statement – tune measurement quality of BBQ is equal to that of 245MHz PLL (or better)
- But, BBQ is in coherent spectrum, more sensitive to
  - Artus kicks
  - IPM kicks
  - chromaticity
  - ‘beam noise’ in general
- With kicks off and chromaticity controlled, expectation is that quality of chromaticity measurement will be equal to (or better than) what we got from 245MHz PLL
- This is sufficient for chromaticity feedback
- Alternative measurement methods are under active investigation, will be tested on SPS in late September
  - advantage is that they are **non-perturbative**

Alternative Measurement Methods

- “Continuous head-tail” using BBQ
  - add a second DAQ channel, looking at reversed diode
  - pickup is a differentiator, first channel (diode in normal orientation) sees head of bunch, second channel sees tail of bunch
  - look at amplitude and phase of tail relative to head during continuous excitation
  - brief study done parasitic to blue beam commissioning at start of Run 6
  - problem? dependence on synchrotron frequency
- Multi-carrier excitation
  - first proposed by Hermann Schmickler (2001?)
  - Measure linewidth by exciting beam on both sides
  - problem? response shape is not what is expected?

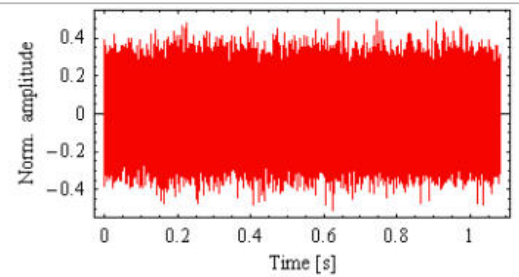


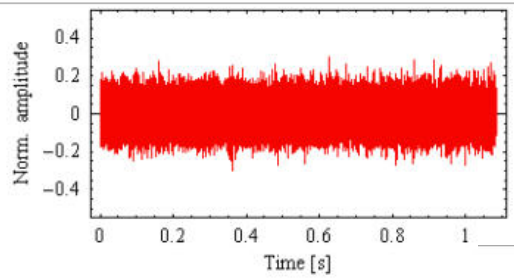
head



tail

$\xi \sim 2$



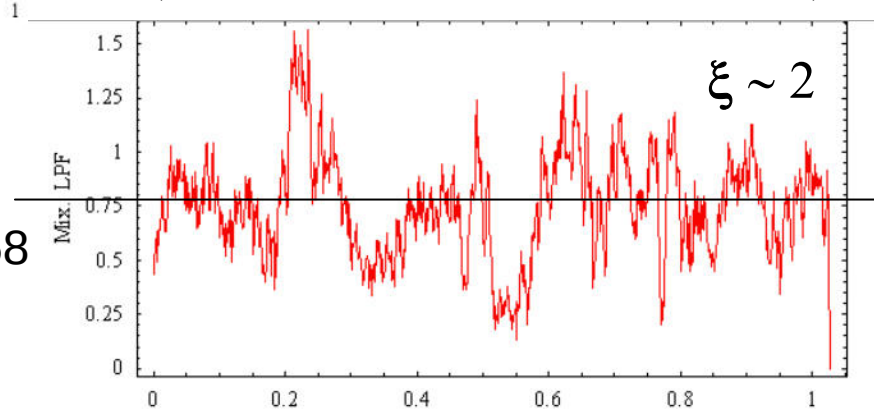


$\xi \sim 6$

1 second

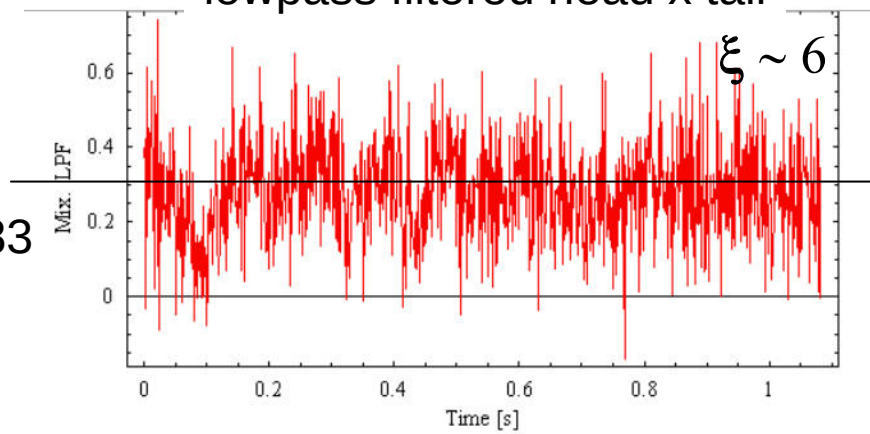
February 2006 RHIC Run 6 - continuous head-tail chromaticity measurement using BBQ (no momentum perturbation)

mean = .758



lowpass filtered head x tail

mean = .283



Conclusions and Run 7 Plan

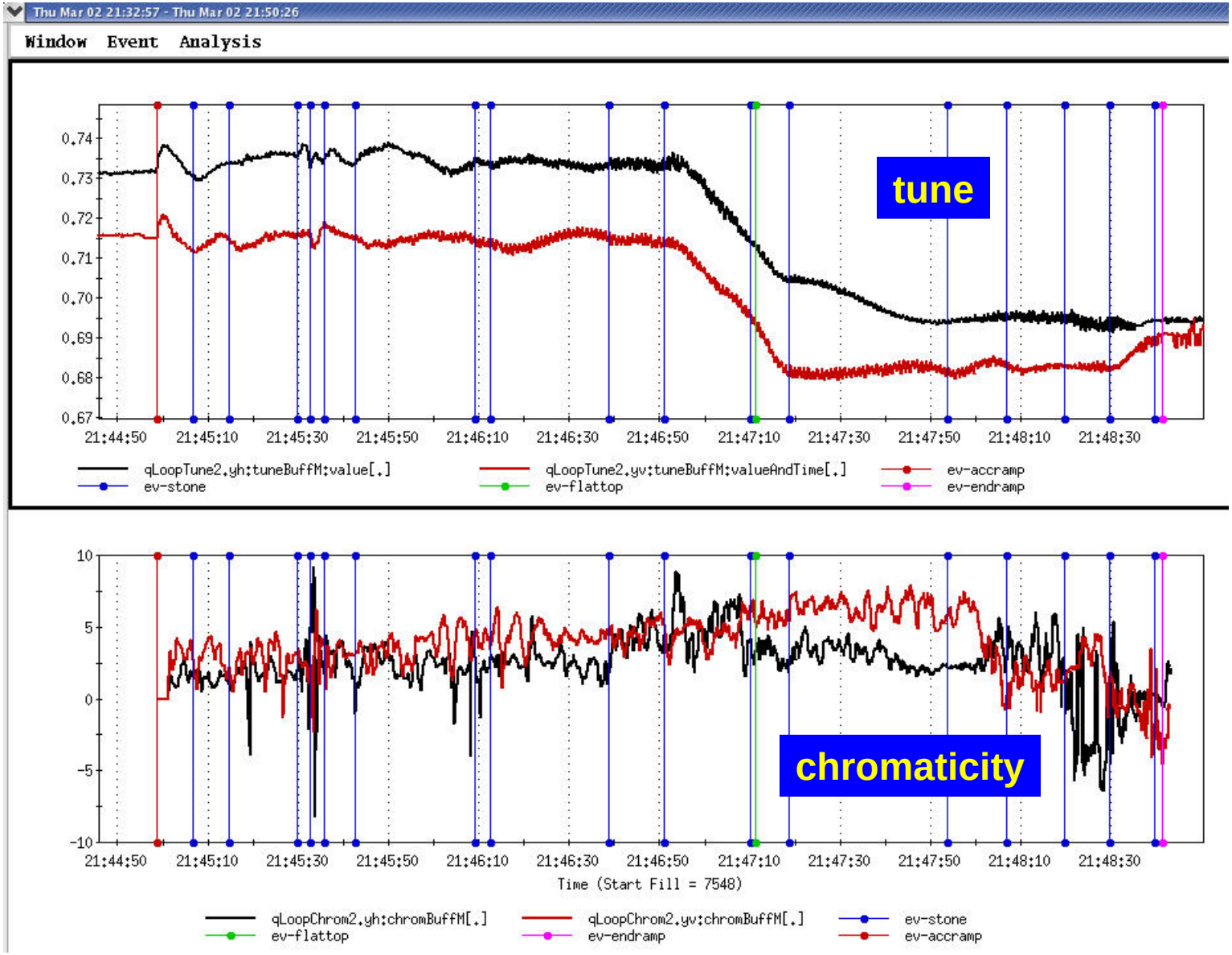
- Improve mains harmonics situation (if possible)
- Fix to phase jumps is in the works
- Next obstacle to operational TF is chromaticity – stabilize loop gains
- Proposal - Run 7 commissioning similar to Run 6, except this time implement chrom feedback rather than coupling feedback (easier?)
  - stabilization at injection of tune, coupling, and chrom drifts – behavior is repeatable, so compensate. Helpful both for BBQ and injection setup in general (time saving during turn-around) (also needed for Jon Laster's phase jump correction)
  - stabilize loop gains – in addition to chrom feedback, add 'sigma loop'
  - study snapback, compensate if possible (more stones?)
  - transition – turn off chrom feedback just before jump, back on when 'measurement valid'
  - Chromaticity application improvements
    - more robust 'error' algorithm
    - resolve sign ambiguity, if possible
    - explore frequency and amplitude of radial modulation
  - Integration with Controls and Magnet system

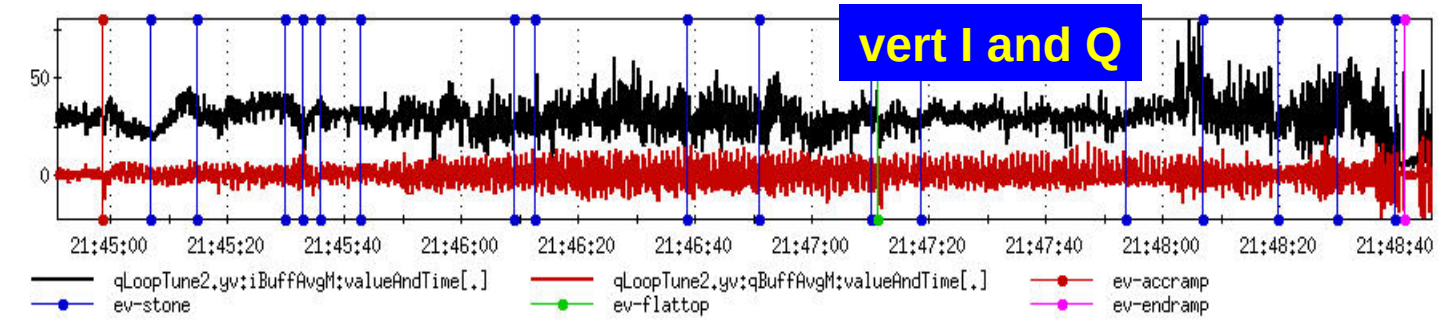
backup slides

90 degree phase jumps

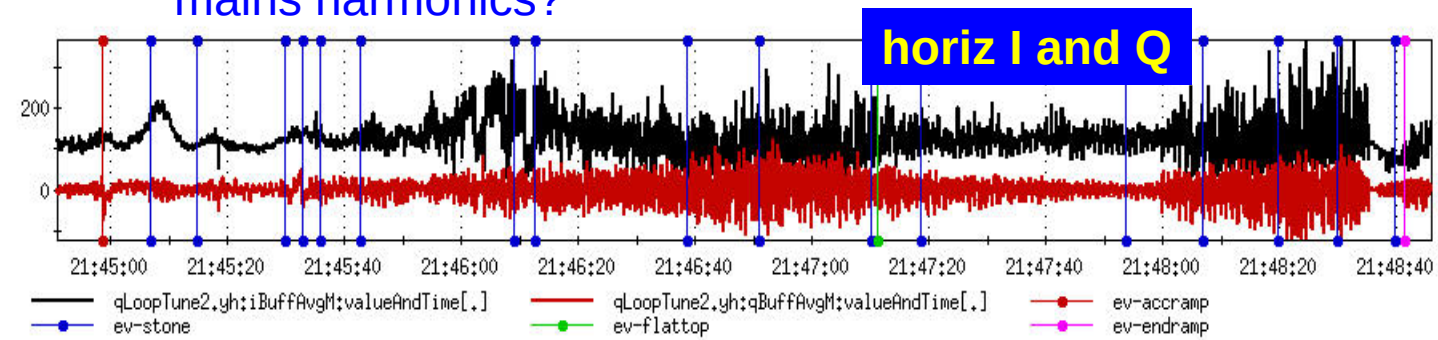
- In principle digitizing and processing phases should remain locked
- In 245MHz PLL the gate array clock ran at 122MHz, would sometimes drop a sample
  - solution was a combination of hardwired reference and DSP correction software (not possible with BBQ)
- In BBQ we are working at audio
  - there should be no problem maintaining clock synchronization
- Problem seems to appear most frequently with fresh beam when returning to injection
- Tried switching NCO clock from 28MHz analog LLRF piped over from 1004 on heliax to V124 RF output
  - no obvious improvement

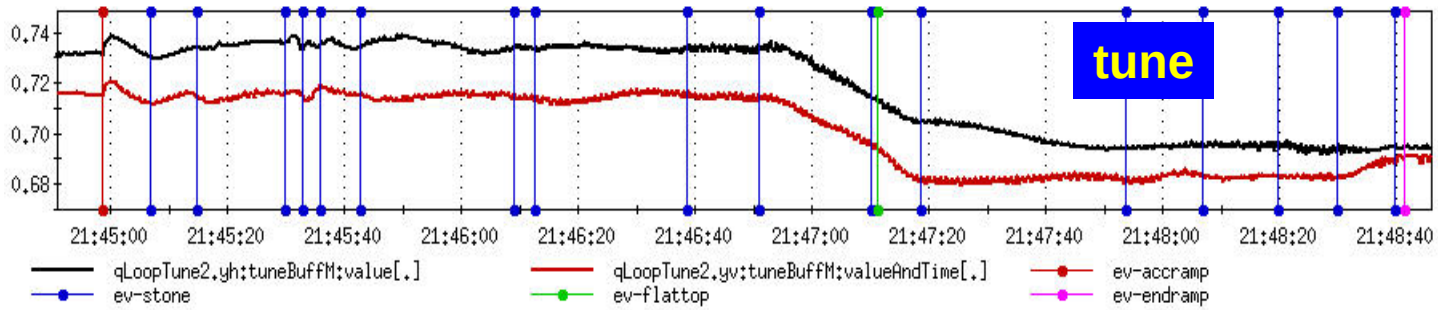
yellow

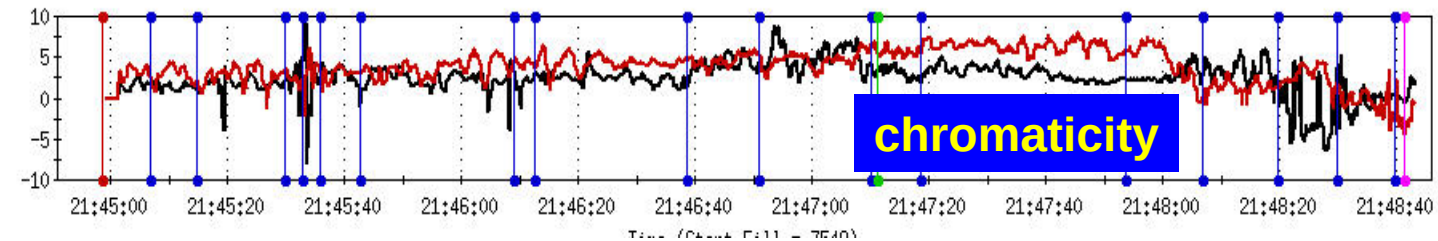

Thu Mar 02 21:32:57 - Thu Mar 02 21:50:26
Window Event Analysis
tune
0.74
0.73
0.72
0.71
0.70
0.69
0.68
0.67
21:44:50
21:45:10
21:45:30
21:45:50
21:46:10
21:46:30
21:46:50
21:47:10
21:47:30
21:47:50
21:48:10
21:48:30
qLoopTune2.yh:tuneBuffM:value[.]
qLoopTune2.yv:tuneBuffM:valueAndTime[.]
ev-accramp
ev-stone
ev-flattop
ev-endramp
chromaticity
10
5
0
-5
-10
Time (Start Fill = 7548)
qLoopChrom2.yh:chromBuffM[.]
qLoopChrom2.yv:chromBuffM[.]
ev-stone
ev-flattop
ev-endramp
ev-accramp



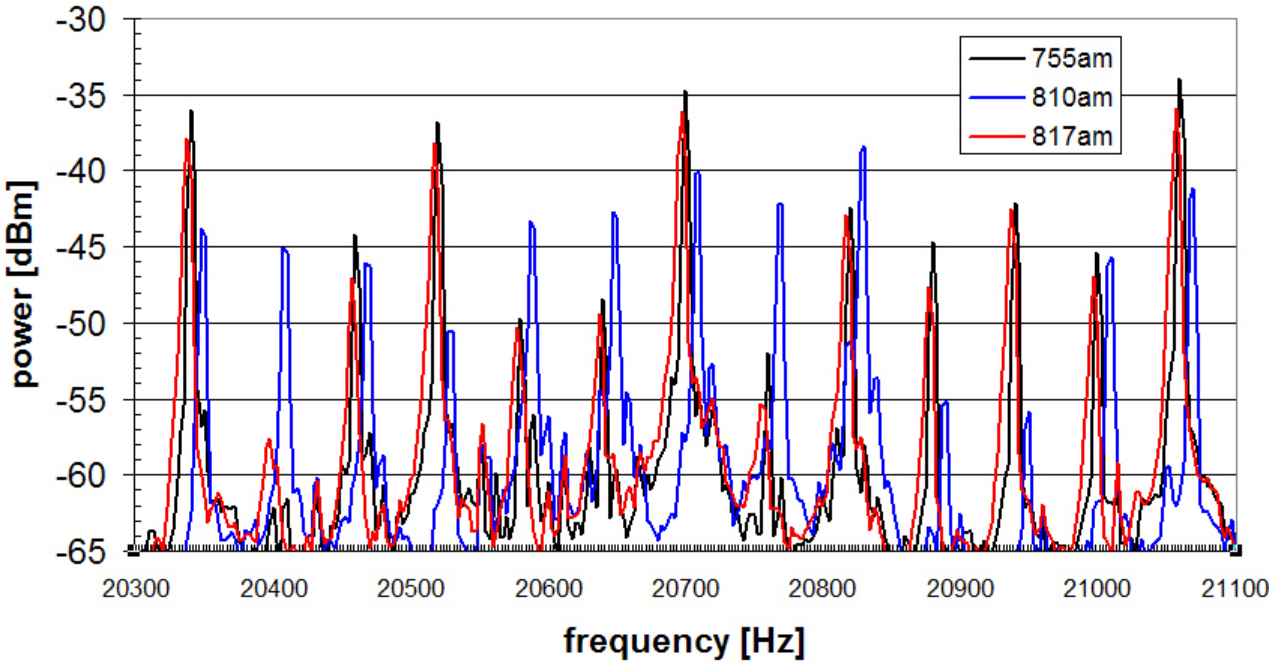
mains harmonics?







12 phase power supply balancing



- At injection, tweak one phase of 12 phase power supply
- Causal relation was observed with pattern of mains harmonics
- The tweak was large – 150μsec, or ~3 degrees at 60Hz
- Pattern changed, but total mains harmonics power remained constant
- Conclusion – not likely to be eliminated by better balancing
- Investigating other possibilities
- **This phenomenon is not understood**

elog entries – head-tail chrom study

10:31 initial chrom very close to 0 -pc, Marek

æ 10:20

10:32 up 2 units

æ 10:22

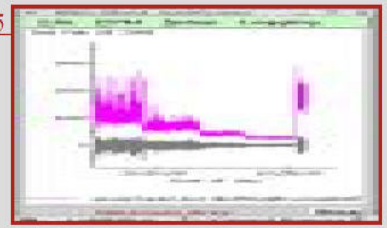
10:32 up 4 units

æ 10:24

10:32 up 6 units

10:32 up 6 units

æ 10:25



æ 10:25

æ 10:26

10:33 back to original setting

10:33 back to original setting

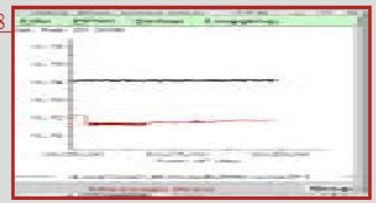
æ 10:27

10:33 down 1 unit

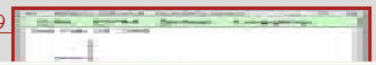
æ 10:28

10:34 down 2 units

æ 10:28

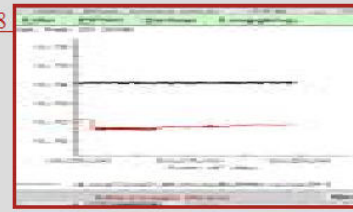


æ 10:29

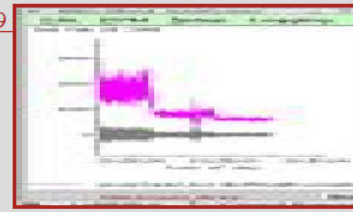


10:34 down 2 units

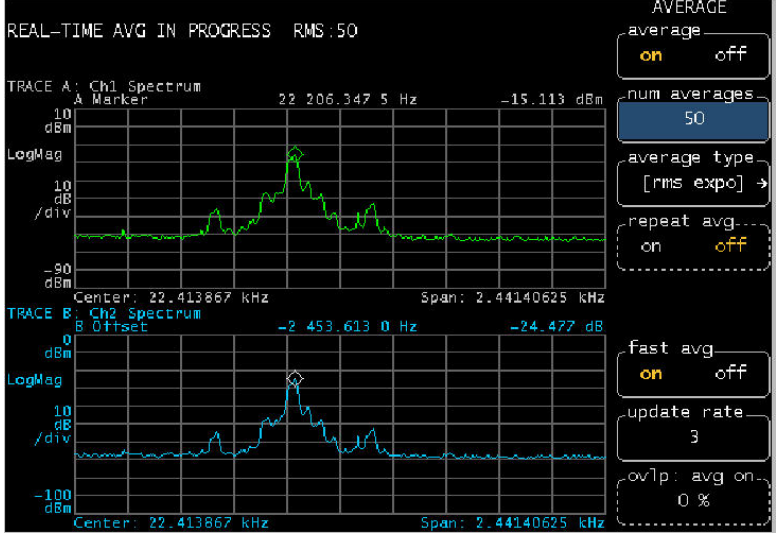
æ 10:28



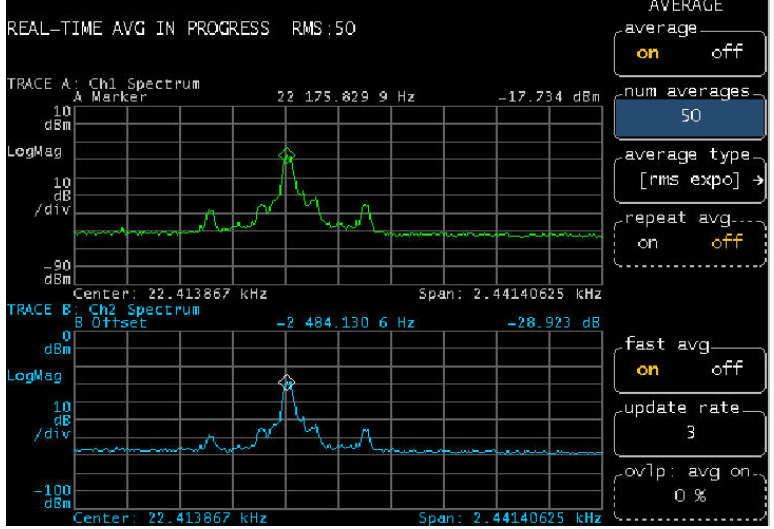
æ 10:29



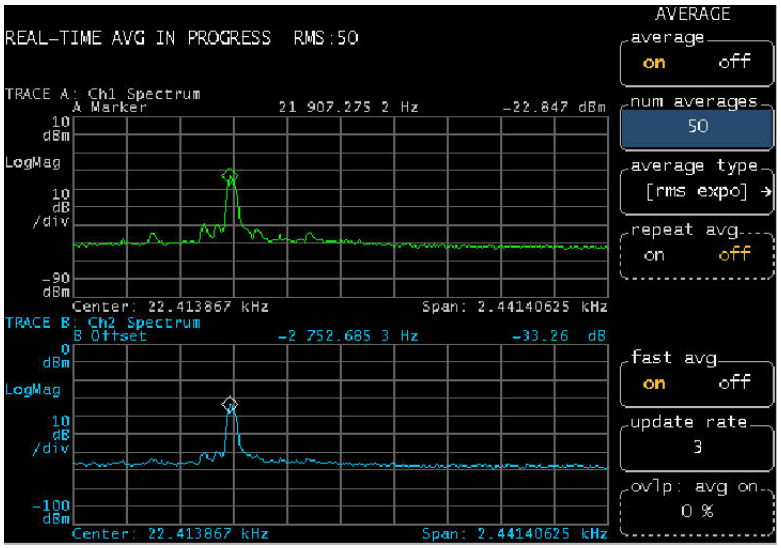
10:34 BBQ chrom study complete, switching b



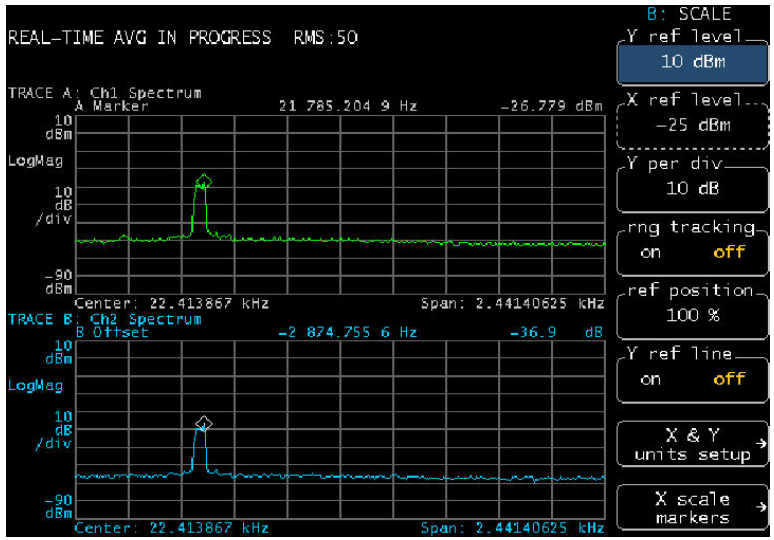
initial



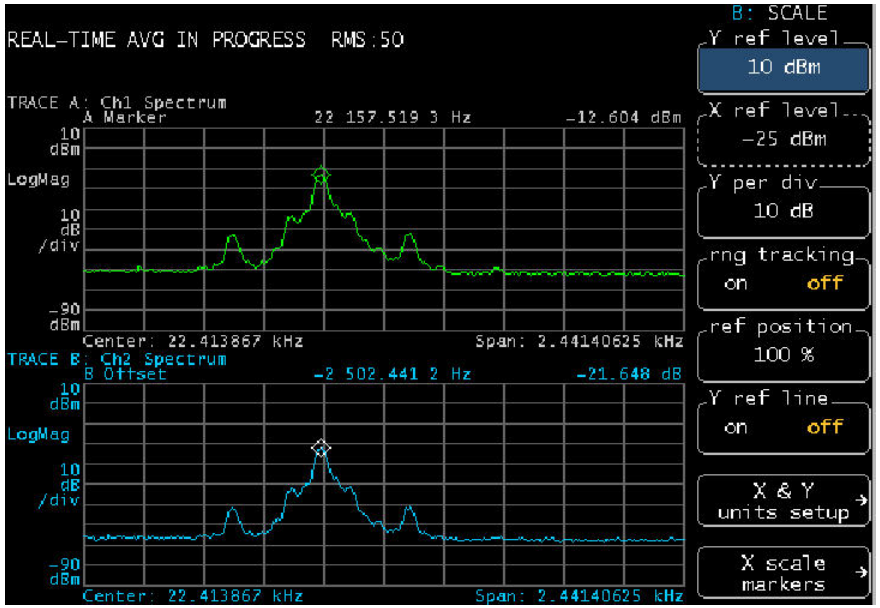
up 2



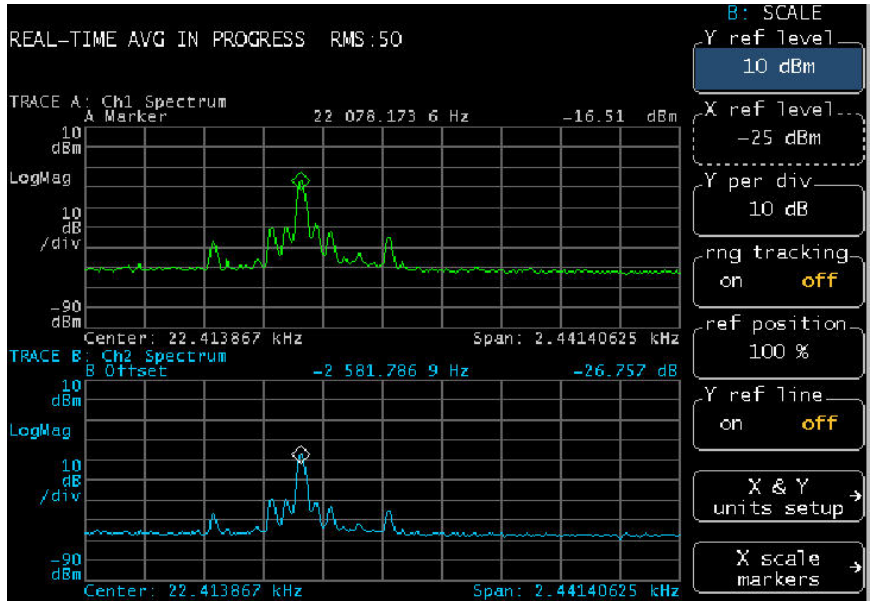
up 4



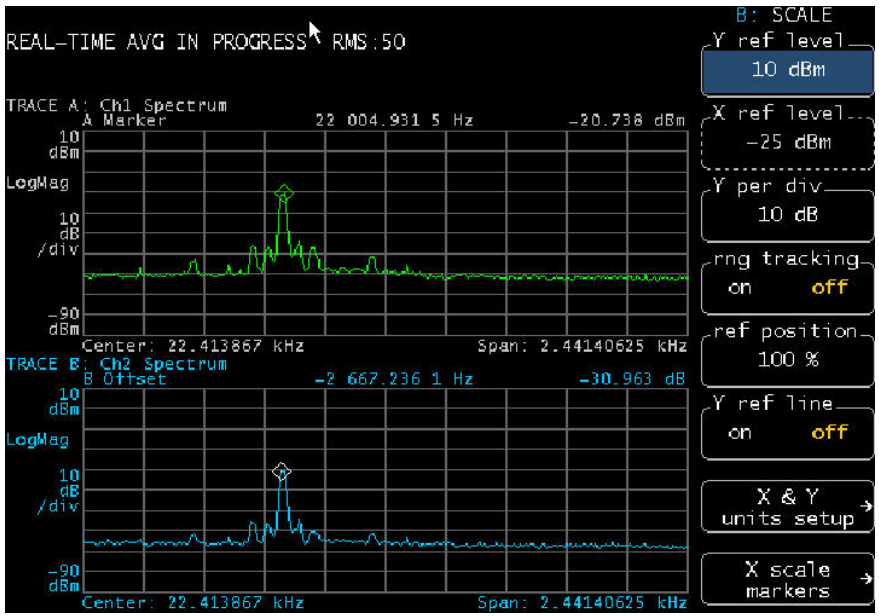
up 6



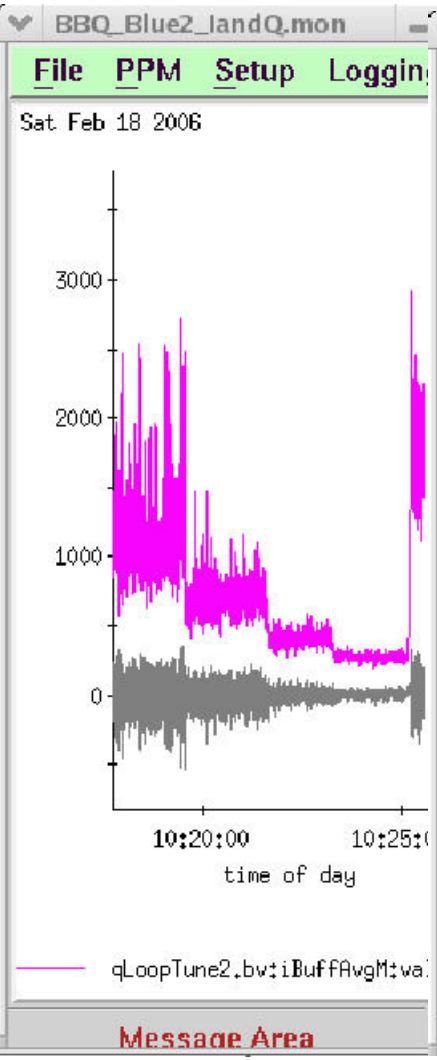
back to init

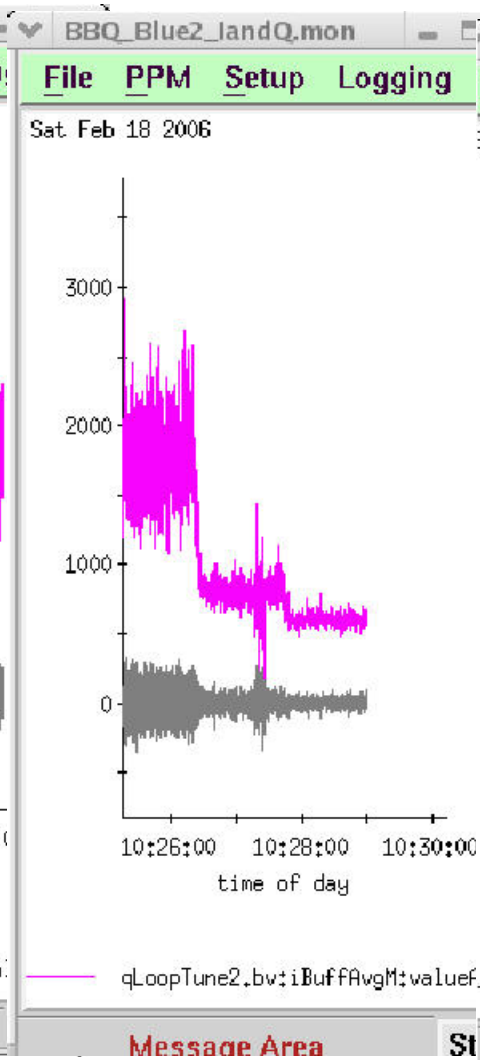


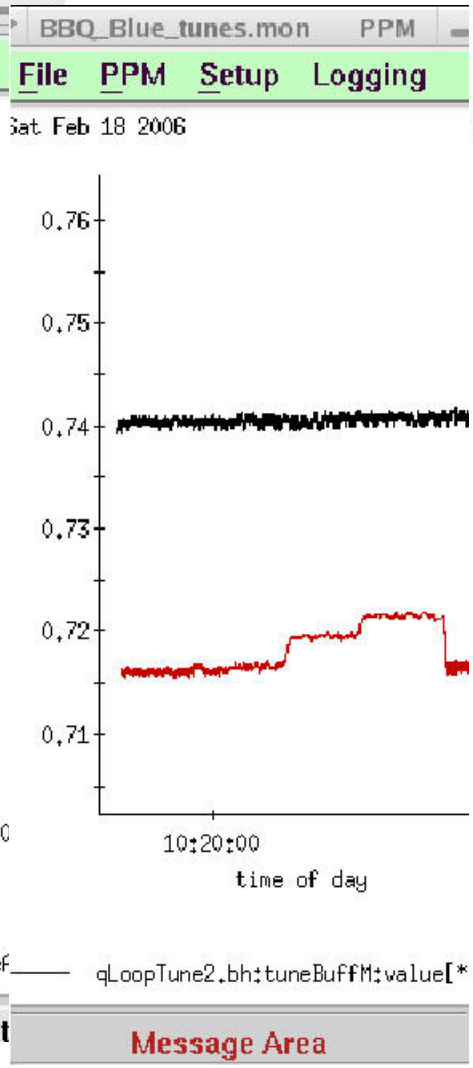
down 1

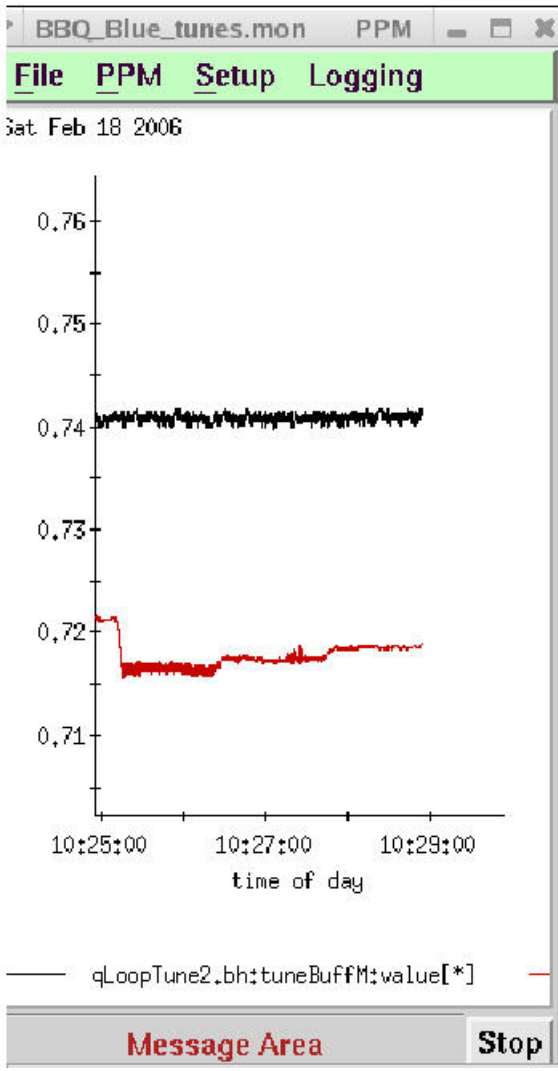


down 2


BBQ_Blue2_landQ.mon
File PPM Setup Loggin
Sat Feb 18 2006
3000
2000
1000
0
10:20:00
time of day
qLoopTune2.bv:iBuffAvgM:va
Message Area


BBQ_Blue2_landQ.mon
File PPM Setup Logging
Sat Feb 18 2006
3000
2000
1000
0
10:26:00
10:28:00
10:30:00
time of day
qLoopTune2.bv:iBuffAvgM:valueF
Message Area
St


BBQ_Blue_tunes.mon PPM
File PPM Setup Logging
Sat Feb 18 2006
0.76
0.75
0.74
0.73
0.72
0.71
10:20:00
time of day
qLoopTune2.bh:tuneBuffM:value[*
Message Area


BBQ_Blue_tunes.mon PPM
File PPM Setup Logging
Sat Feb 18 2006
0.76
0.75
0.74
0.73
0.72
0.71
10:25:00
10:27:00
10:29:00
time of day
qLoopTune2.bh:tuneBuffM:value[*]
Message Area
Stop